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VIEW ON THE TRUCKEE-CARSON RECLAMATION PROJECT, SHOWING THE NATIVE VEGETATION TYPICAL OF THE DESERT LANDS.

(Photographed August 27, 1907.)

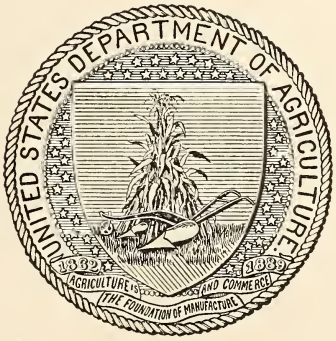
U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 157.
B. T. GALLOWAY, *Chief of Bureau.*

THE TRUCKEE-CARSON EXPERIMENT FARM.

BY

CARL S. SCOFIELD, Agriculturist in Charge,
AND
SHOBER J. ROGERS, Farm Superintendent,
Western Agricultural Extension.

Issued August 11, 1909.



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Chief of Bureau, BEVERLY T. GALLOWAY.
Assistant Chief of Bureau, ALBERT F. WOODS.
Editor, J. E. ROCKWELL.
Chief Clerk, JAMES E. JONES.

WESTERN AGRICULTURAL EXTENSION.

SCIENTIFIC STAFF.

Carl S. Scofield, *Agriculturist in Charge.*
Frank B. Headley, *Scientific Assistant.*
William A. Peterson, *Superintendent, Yuma Experiment Farm.*
Stephen H. Hastings, *Superintendent, San Antonio Experiment Farm.*
Shober J. Rogers, *Superintendent, Truckee-Carson Experiment Farm.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 7, 1909.

Sir: I have the honor to transmit herewith a report entitled "The Truckee-Carson Experiment Farm," by Mr. Carl S. Scofield and Mr. Shober J. Rogers, and to recommend that it be published as Bulletin No. 157 of the series of this Bureau.

The Truckee-Carson Experiment Farm has been established at the request of the Reclamation Service of the Department of the Interior and is one of the several field stations recently established on certain of the reclamation projects in the western United States. It is the purpose of these field stations to enable the investigators of the Department to carry out experiments and investigations bearing upon the agricultural problems of these irrigated sections, to test new crops, and to aid the farmers in successfully meeting their new conditions.

The present report deals with the agricultural situation on the Truckee-Carson project and with the lines of work so far undertaken on the experiment farm.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE TRUCKEE-CARSON EXPERIMENT FARM.

INTRODUCTION.

The Truckee-Carson Experiment Farm was established in the autumn of 1906 by the Bureau of Plant Industry of the United States Department of Agriculture, in cooperation with the United States Reclamation Service and the Nevada Agricultural Experiment Station. The farm is located 1 mile south of Fallon, Nev., the principal town on the Truckee-Carson Reclamation Project.

This experiment farm is intended to serve as a place where the agricultural problems of the Truckee-Carson Project may be worked out under the direction of the specialists and experts of the United States Department of Agriculture and the State experiment station of Nevada. In so far as these experts and specialists are acquainted with local problems and are prepared to make definite recommendations, these recommendations are carried out on the experiment farm as demonstrations. Every effort is made by the management of the farm to keep in close touch with the farmers of the community, to understand their problems, and to bring these to the attention of the specialists best qualified to deal with them. It is also the aim to help the farmers in every way possible by securing information for them, by carefully testing varieties of crops, trying new crops, and by comparing different methods of tillage and irrigation.

It is not the aim to operate this as a model farm, nor primarily as a demonstration farm. The region is new, agriculturally, and the body of knowledge available is too limited to warrant extensive demonstrations which are unsupported by experiments.

In the following pages there is given a brief description of the region from an agricultural standpoint, something of its agricultural possibilities and limitations, and an account of the lines of work under way on the experiment farm.

DESCRIPTION OF THE REGION.

The Truckee-Carson Project lies near the western edge of a great valley in western Nevada, a depression that was once the bed of a lake similar to the Great Salt Lake of Utah. This lake bed has been named by geologists the Lahontan basin. All that now remains are a few small isolated lakes and marshes. The major portion of this

lake bed is a desert. It lies close to the eastern slope of the Sierra Nevada Mountains, which, rising to a height of 12,000 feet or more, catch much of the moisture borne inland by the air currents from the Pacific Ocean. So effectual is this mountain barrier in intercepting these moisture-laden currents that the rainfall in the valley is little more than 2 inches a year.

The valley floor lies at an altitude of about 4,000 feet above sea level. The topography is somewhat rough, being broken by high buttes and small groups of hills, which are often skirted by shelving terraces, while in the intervening flats there are many small sand hills formed by the wind.

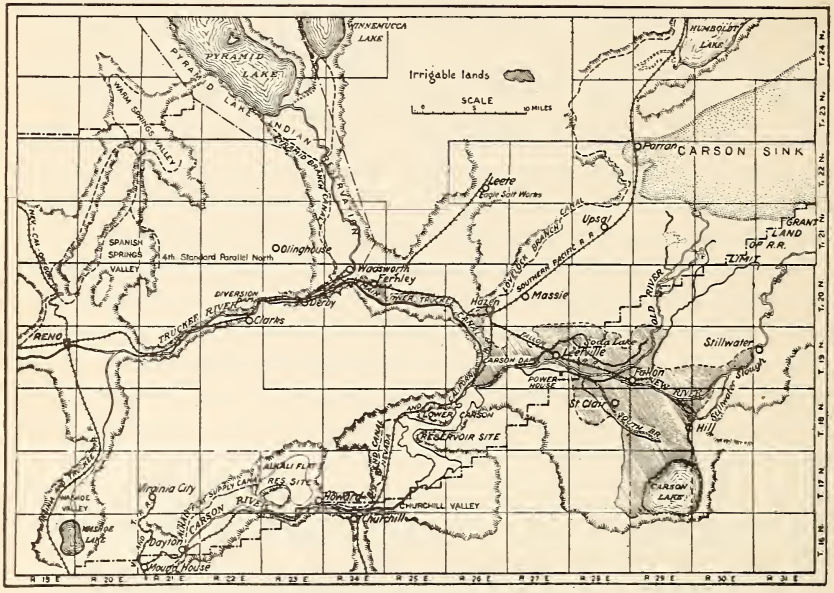

FIG. 1.—Map showing the location of the Truckee-Carson Reclamation Project and adjacent territory.

Into this valley from the west flow two important rivers, the Carson and the Truckee. These are fed by the rain and melting snow of the high Sierras. The combined water of these two rivers is used to irrigate the body of land known as the Truckee-Carson Project.

The construction work necessary to distribute this water for irrigation has been done by the Federal Government under the authority of the reclamation act, approved June 17, 1902. Of the 350,000 acres of irrigable land included in this project, some is held in private ownership by early settlers, some is offered for sale by the Southern Pacific Railroad Company—being a part of the land grant to that company—some has been filed upon by new settlers under the homestead law as modified by the reclamation act, and some is still open for entry. The accompanying map (fig. 1) shows the location of the

project and some of its more important topographic features, as well as some of the cities and towns included or adjacent.

CLIMATE.

Table I, compiled from the records of the United States Weather Bureau, shows approximately the temperature conditions that exist in the region under discussion. It will be noted that the maximum temperature recorded for four years is 103° F., while the minimum is −2° F. During the winter of 1907–8 the lowest temperature reached was 12° F.

TABLE I.—*Mean, maximum, and minimum temperatures at Fallon, Nev., for four years, 1904–1908.*[a]

Month.	1904.			1906.			1907.			1908.		
	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
January	26.9	56	0	31.7	60	6	30.7	64	−2	34.8	56	12
February	38.2	65	9	40.7	69	11	45.4	72	22	38.6	71	16
March	43.8	69	15	.....	.....	.....	42.4	70	12	42.6	78	15
April	49.4	83	20	50.5	84	18	54.8	81	29	52.6	89	18
May	58.4	85	28	56.6	84	31	56.3	88	29	51.6	80	25
June	66.0	93	39	63.4	90	38	62.0	93	33	62.8	93	35
July	73.7	98	48	78.2	101	53	72.0	99	44	76.4	101	51
August	.....	.....	.....	74.6	98	42	69.2	99	40	72.2	103	36
September	.....	.....	.....	62.8	90	34	60.1	95	29	61.5	94	26
October	51.3	76	30	52.3	88	22	.....	.....	.....	48.6	82	15
November	.....	.....	.....	37.8	81	−1	39.8	76	18	40.7	68	6
December	.....	.....	.....	35.9	59	−2	37.7	72	15	28.8	56	−2

[a] The records of temperature at Fallon for 1905 are not obtainable.

The length of the summer period between frosts is shown in Table II. The stations to which the records apply are located in different parts of the region (see map, fig. 1), and it will be noted that there are some marked differences in the frost dates recorded. The variation in topography may account for some of these differences, but it is probable that there are also errors in observation due to the inexperience of the observers.

TABLE II.—*Dates on which the last killing frost in spring and the first killing frost in autumn occurred, as reported by voluntary observers at points on the Truckee-Carson Project, 1905–1908.*[a]

Year.	Frost.	Carson dam.	Leetville.	Soda Lake.	Fallon.	Hazen.	Fernley.
1905	Last	.....	.....	.....	.....	.....	.....
	First	.....	.....	.....	.....	Oct. 8	.....
1906	Last	.....	.....	.....	May 31	May 28	.....
	First	Sept. 4	Oct. 4	Oct. 18	Oct. 4	Oct. 18	.....
1907	Last	Apr. 20	May 2	.....	May 14	June 15	June 14
	First	Oct. 29	Sept. 19	Sept. 18	Sept. 19	.....	Oct. 4
1908	Last	May 15	May 9	May 16	May 30	.....	May 8
	First	Sept. 26	Sept. 26	Sept. 25	Sept. 25	.....	Sept. 26

[a] Compiled from official reports of the U. S. Weather Bureau.

The rainfall of the region is so slight as to be negligible as a factor in supplying moisture for crops. The records available show an annual mean precipitation of about 2.5 inches, of which the major portion falls in the winter months.

Observations as to the atmospheric humidity are too inadequate to be of value, but it may be said that the air is usually very dry. During the past year observations have been made as to the quantity of water evaporated from a free-water surface. The results are given in Table III.

TABLE III.—*Quantity of water (inches in depth) evaporated from a free water surface near Fallon, Nev., 1908.*[a]

May.	June.	July.	August.	September.	October.	November.	December.
Inches. 7.91	*Inches.* 10.22	*Inches.* 11.74	*Inches.* 10.84	*Inches.* 5.50	*Inches.* 4.00	*Inches.* 2.27	*Inches.* 0.65

[a] The figures shown in Table III were obtained at the experiment farm from a tank installed for the purpose of measuring the evaporation. This tank is made of galvanized iron, 4 feet in diameter and 2 feet deep. It is embedded in the earth only a few inches. The water in the tank is kept about 18 inches deep.

The wind is often an important factor of the climate in a desert region, particularly where the soil can be easily blown, as is the case on the Truckee-Carson Project. There are no accurate records of air movement for this section, but it has been found by experience that the winds are not of sufficient strength and frequency to justify the use of windmills for pumping the farm water supply, although the wells are all very shallow. Notwithstanding this fact, windstorms of considerable violence are likely to occur during the spring, and they may do considerable damage in drifting the soil from newly leveled or otherwise unprotected fields. On this account new settlers on the lighter soils find it necessary to use care in removing the brush and leveling land.

Wind-breaks of tamarisk and cottonwood should be started on new farms as soon as water is available and before any large proportion of the native brush cover is removed. Both of these trees are well suited to this locality. They may be propagated by cuttings, and grow vigorously from the first.

WATER SUPPLY.

The water supply used in irrigating this project is obtained from the Carson and Truckee rivers, which rise on the eastern slope of the Sierra Nevada. The water of the Carson River is directly diverted for use on the project, and the water of the Truckee is carried through a long canal and delivered into the Carson at a point in that river above the dam diverting to the irrigation ditches. The Carson River

drains the lower foothills of the mountains, and its water supply is usually exhausted by midsummer. The Truckee, on the other hand, takes its rise in Lake Tahoe, high in the mountains, and consequently its discharge is more regular throughout the season. Both rivers, however, are subject to high floods, so that a considerable quantity of water is wasted in the spring months. Additional construction work is contemplated to provide storage reservoirs in order to save as much of this flood water as possible to supplement the midsummer flow of the streams. At present the irrigable land on the project somewhat exceeds the water supply during the late summer.

The system of water distribution on the project carries the water to each farm unit. The farm units are usually 80 acres in size, except near the towns, where they are 40 acres. A prospective settler selecting a farm unit, not already filed upon, will make homestead entry in the usual way, paying the usual fees and commissions and one installment of the charges which are assessed to cover the cost of the construction by which the water is furnished, and the cost of maintaining the distributing system. The construction cost on the project is now $30 per acre of irrigable land, which is payable in not more than ten annual installments. In addition to the construction charge there is an annual charge for maintenance and operation of 60 cents per acre of irrigable land. When the usual requirements of the homestead law have been complied with and one-half of the irrigable area has been reclaimed and the construction and other charges are fully paid, the homesteader secures a patent to his land and owns also the permanent water right which attaches to it.

DRAINAGE AND UNDERGROUND WATERS.

The main body of the irrigable land lies in the valley of the Carson River. This stream previous to its use for irrigation purposes flowed out into the desert, emptying partly into Carson Lake and partly into Carson Sink, where the waters evaporated. The river's course was a meandering one, and its channel changed from time to time as a result of flood modifications. In addition to the channel flow there was a very considerable movement of underground water through porous strata a few feet below the surface of the ground. This underflow has become a factor of considerable importance. In the lower places it is often so near the surface that capillary connection is established, and evaporation from the surface soil leaves deposits of salt. Since the normal flow of Carson River has been supplemented by water from the Truckee and both are distributed over the land for irrigation, this underflow has been somewhat increased and the underground water table has risen slightly, causing considerable

anxiety among settlers on the lower land on account of possible trouble from alkali. When the system of distribution was installed a system of drainage ditches was also put in throughout the lower lands. When this drainage system is perfected it will probably be adequate to keep the water table below the point where it can cause serious and extensive damage.

MARKETS AND RAILROAD FACILITIES.

In view of the fact that a relatively large body of land, hitherto unused, is rapidly being made productive, the need of suitable markets for the agricultural products becomes acute, and consequently the question of the railroad facilities of the region is an important matter.

The Truckee-Carson Project lies immediately adjacent to the main line of the Southern Pacific, between San Francisco and Ogden. A short branch line of this railroad extends from Hazen, which is a junction point on the main line, to Fallon, the principal town of the project. From Hazen a railroad also runs south into the Goldfield and Tonopah mining districts, and thence southeastward to connect with the San Pedro, Los Angeles and Salt Lake Railroad. Direct railroad communication is therefore possible, not only with the large markets of California, but also with the large mining towns of Nevada. These mining towns have practically no agricultural lands immediately adjacent to them; hence, they are good markets for all kinds of agricultural products, and prices are high. There are also a number of mining camps in the hills south and east of the project to which the railroad has not yet been extended. These camps also, having no local food supply, are good markets for products raised on the project.

AGRICULTURAL CONDITIONS.

The agricultural lands of the Truckee-Carson Project may be conveniently divided into two distinct classes. One class consists of the lands lying close to the river and slough channels and along the border of Carson Lake. All these lands, regardless of their mechanical texture, carry a considerable amount of organic matter and are consequently very fertile and, where not too wet, are capable of immediate crop production. The other class comprises the more truly desert lands, which are conspicuously devoid of organic matter and which require special treatment before they reach a condition of maximum crop production.

Two distinct soil types are found in the desert lands. One type is a very sandy soil which, when exposed, is easily drifted by the

wind. The other is known locally as "hard land," or "clay flats." There is, of course, considerable variation in the mechanical texture of both types. Some of the soils are nearly pure coarse sand, while others carry a large quantity of fine material and verge on a sandy loam. The soil of the hard lands, or clay flats, is often a mixture of rather coarse sand and clay, containing some cementing material. Both soil types are irregularly distributed throughout the project, sometimes occurring in small areas side by side. But the sandy soil is by far the more extensive in the aggregate, sometimes occupying large areas to the exclusion of the hard lands. A soil survey of the project is about to be started by the Bureau of Soils. When that is completed more exact information will be available on the classification, location, and extent of the soil types.

While the soils along the river channels and lake bed present few obstacles to securing immediate crop production the reverse is true of the desert soils. These latter do not respond immediately to tillage and irrigation as desert soils are popularly supposed to do. It is true that a part of their apparent infertility may be due to a variety of extraneous causes; for instance, crop failures are sometimes due to windstorms or nonadaptability of the crop tried. It is certainly true, however, that considerable care is necessary in handling these desert soils to insure crops the first season or two. After they have been irrigated and cultivated for a time they become very productive.

NATIVE VEGETATION.

The soils along the river channels and around Carson Lake support a relatively luxuriant native growth, the most conspicuous features of which are the cottonwood trees, the willows, sagebrush, rabbit brush, wire-grass (species of the genus Carex), a number of sedges, and some tules, chiefly cat-tail. In a few areas some clovers (species of the genus Trifolium) and one or two species of vetch occur. There are considerable areas occupied almost exclusively by tall grasses, chiefly Elymus.

The vegetation of the desert is much less abundant, both in amount of growth and in species represented, than that of the river-bottom land. No trees occur on the desert soils. The chief elements of the vegetation are greasewood (Sarcobatus), sagebrush (Artemisia), and rabbit brush (Chrysothamnus). There is also a considerable variety of small annuals which spring up and flourish after the rains, among them the so-called desert verbena (Abronia), one or two species of Astragalus, and a few grasses. (See Pl. I.)

EARLY SETTLEMENT.

The first agricultural development of this region began about the middle of the last century, when there was some use of the Carson River water on the land immediately adjacent to it. This agriculture was limited in extent, and was mostly connected with stock raising on the range lands in the adjacent hills. The irrigated land was held in large bodies, and was used chiefly for the production of hay and grain. As the Carson River usually went dry before midsummer, it was unsafe to depend upon crops requiring water late in the season.

Upon the completion of the present irrigation project, in 1906, a considerable extension of farming immediately took place. New settlers came in, some of whom bought land which had previously been under ditch and others took homesteads on the desert land. The recent extension of mining enterprises in the adjacent hills has made a good market for vegetables and truck crops, while the presence of the work stock used in the valley for ditch construction and for opening the new lands for farming has caused large demands to be made for grain and forage, so that up to the present prices for agricultural products have been good. The extension of farming to the desert lands has brought up many problems of the utmost importance to the new settlers, some of which may be solved by experience elsewhere, but many others must be worked out locally to insure correct solution. It is for the purpose of helping these new settlers that the Truckee-Carson Experiment Farm has been established.

CLEARING AND LEVELING THE LAND.

One of the problems which confronts a new settler, after his land has been selected and his buildings put up, is the clearing and leveling of his land. There are a number of ways in which this can be done, depending upon the equipment available. One of the most economical ways is first to go over the land with a railroad rail, with a team at either end. This breaks down the brush, snapping off the brittle stems of the desert shrubs. This brush can then be forked into piles and burned, or hauled off the field, to be used as fuel. The land is then plowed with a heavy breaking plow, or sometimes leveled with a scraper without plowing.

There is a diversity of opinion as to the best method of preparing land for irrigation. The most economical method on this project is to throw up borders which conform somewhat to the natural topography, forming checks of various shapes which can be flooded from the ditch which is carried along the high contour line. Some of the land is so nearly level that regular checks can be made by

throwing up borders and smoothing off the occasional sand hills which occur. In view of the danger from wind action mentioned, it is very important to leave uncleared any land which is not to be immediately leveled and irrigated. On the sandier soils it will often be found advisable to clear and level the land in relatively narrow strips, leaving the brush-covered land between to break the force of the wind until artificial wind-breaks may be provided.

The matter of wind-breaks should be given the earliest attention by the new settler. Not only should trees and shrubs be planted to shelter the fields, but the house and the corral should also be provided with a shelter of trees. These will furnish shade and protection from the wind, both of which are very necessary to comfort, besides improving the appearance of the place. Cottonwoods, honey locusts, black locusts, Russian olives, and tamarisks should be used abundantly both around the farmstead and along the ditch lines. Not only are trees valuable for wind-breaks and shade purposes, but they will soon furnish fuel, which is now and probably will continue to be very high priced. Indeed, the fuel situation is so acute that every effort should be made by the farmers, both individually and as a community, to secure the planting of extensive areas to trees. Scattered over the project there are a number of areas of relatively little value for agricultural purposes upon which trees would grow rapidly, and time should not be lost in getting trees started wherever possible.

THE FIRST CROPS.

The first crops on new land in this region are usually grain, alfalfa, and vegetables. Alfalfa, though often a little difficult to start, thrives well when once established and ranks as the most important crop of the region. On land which contains any appreciable quantity of organic matter there is little or no difficulty in growing alfalfa if the land is in good tilth when the seed is sown. Alfalfa can be sown at almost any season of the year, but does best when sown either in April or in August. On new land, where organic matter is deficient or absent, and particularly where there is danger from sand storms, the best success in starting alfalfa is secured where wheat or barley is sown as early in the spring as weather conditions will permit, which is some time in March. When the grain is a few inches high the alfalfa is sown in it with a drill. The grain serves as a protection to the young alfalfa plants, both from the wind and the sun, and also tends to prevent crusting of the surface soil, which is a serious matter, particularly on the hard lands. For the best results with alfalfa it is desirable to cut the grain for hay before it is quite mature. This early cutting gives the alfalfa a chance to make good growth before cold weather sets in.

Wheat, oats, and barley are all used for grain. Winter wheat can be sown in the fall, and it is probable that some varieties of winter barley may be found that will thrive well, but so far no adequate tests have been made upon which to base recommendations as to the best varieties of this or of any other cereal. Where land is not ready for seeding in time for wheat or oats, sorghum or millet could be grown for forage. The amber varieties of sorghum and the German millets promise the best results.

POSSIBLE AGRICULTURAL INDUSTRIES.

In considering the possible agricultural industries of this, as well as of any other region, the most important factors, aside from the natural conditions, are the present and future marketing facilities, labor supply, and the inclinations of the people themselves. The present indications are that some form of live-stock industry must occupy a large place in the future agriculture of the Truckee-Carson Project.

TRUCK CROPS.

For the present and for some little time to come truck crops of the heavier class, such as potatoes, onions, cabbage, and the root crops, will be important features. However, these are relatively intensive industries, and there is hardly a sufficient market at hand or in sight to justify the use of the major portion of the irrigated lands of this project for such crops. It is hardly probable that these crops can be produced to compete in the California markets with similar crops grown in the San Joaquin and Sacramento valleys, and certainly it is not to be expected that under existing conditions they can be profitably sold in the markets farther east.

STOCK RAISING AND DAIRYING.

Some form of stock farming, however, may be expected to provide use for all the land now irrigable in this region, and even for a very considerable extension. With dairying, for instance, as the major industry of this project a number of subsidiary industries might very well be given considerable emphasis. Butter is a concentrated and high-priced product on which freight is a relatively small item.

With the increase of forage production on the project it would be more profitable for farmers to feed their forage and grain to dairy cows than to attempt to ship it out of the country. Once an abundant supply of forage and grain can be provided, cooperative creameries should be organized when the necessary cows are available. It is very important, however, that this industry should grow up gradually. Many costly mistakes can be made by rushing into the dairy business

too rapidly. Dairy cows must be bred on the project. They can not be profitably purchased in sufficient numbers to warrant the establishment of a large industry. Men must learn to cooperate in the creamery business before they can hope to succeed, and, above all, good machinery and good butter makers must be secured. Without these it is useless to expect high prices for the product. It is also necessary before any extensive dairy business can be built up to provide pastures in addition to the alfalfa hay lands. For this purpose the proper kinds of grasses must be found and proper methods learned for establishing the pastures. There is every indication that good grass pastures can be established and maintained on the project. These pastures, supplemented by corn, barley, oats, and root crops, all of which can be grown profitably, will furnish a food supply for dairy stock which should be both cheap and adequate. With the dairy industry as a center a number of intensive subsidiary industries may be developed.

FRUIT RAISING.

In addition to the truck crops already mentioned there is every reason to believe that a considerable number of small fruits can be produced with profit, and the meager information at hand would indicate also that a number of orchard fruits, such as apples, pears, and plums, might be profitable as side lines on many farms. It is important to keep in mind, however, that these industries to be most profitable must be subsidiary to the main farm operations. It is hardly to be expected that the Truckee-Carson Project will prove exceptionally well suited to fruit or truck-crop production for some time to come.

SUGAR BEETS.

Another industry which at present, at least, should be considered as a subsidiary one is the production of sugar beets. Experiments indicate that sugar beets of excellent quality can be grown on this project. Sugar-beet growing, however, demands the erection of an expensive factory, and it also requires a considerable amount of hand labor, so that it is hardly to be hoped that sugar-beet production on an extensive scale will be developed on this project in the near future.

SUBSIDIARY PRODUCTS.

There are many other lines of production, both of crops and of live stock, that suggest themselves as being of good promise in a subsidiary way. The production of early lambs and hog raising are lines that go hand in hand with the general farming to which this region seems best adapted. At the present time the supply of eggs and other poultry products is far below the demand. Growers who make a

specialty of the fancy truck crops are also needed to supply the local and adjacent markets. Every farmer should keep in mind that prices of farm products are regulated by the law of supply and demand. Specialization and rapid extension in the production of any but staple products are likely soon to flood the market and result in much wasted effort.

THE EXPERIMENT FARM.

The experiment farm is located 1 mile south of the town of Fallon. It includes 160 acres, and its soil is typical of a large part of the desert land of the project, both the sandy and clay lands being well represented. None of the river-bottom or slough land of the project is included in the farm. The topography is rough and probably one-fourth of the land lies above the level of the supply ditch.

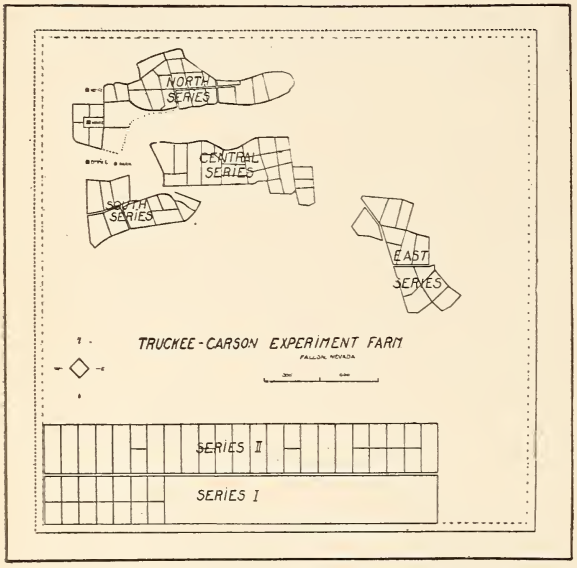

FIG. 2.—Diagram showing the location of the fields and farm buildings on the Truckee-Carson Experiment Farm.

When work was begun on the farm in September, 1906, there were no fences or improvements of any kind and the land lay untouched in its native desert condition. Since that time 40 acres of land have been leveled and put under ditch. The farm has been fenced and equipped with two small dwellings, an office building, and a barn and machine shed. A working equipment of farm machinery has been purchased and the necessary work animals have been hired as needed.

The accompanying map of the farm (fig. 2) shows the fields that were available for use during 1908 and the location of the farm buildings. Additional land is being leveled and prepared for use as opportunity offers. The working force of the experiment farm consists of a superintendent and two or three laborers.

THE "HARD LANDS," OR "CLAY FLATS."

In view of the fact that the clay flats which occur on the farm and elsewhere throughout the project appeared to present one of the most

serious difficulties likely to be met with by the new settlers, experimental work was begun on 15 acres of land on the farm, which lie on this soil type. The land was first leveled and put into checks of one-half and one-fourth acre each, and a number of different methods of treatment were used in preparing the seed bed and putting in the crops. A large variety of crops were also tried the first year, many of which failed completely. Through these experiments much was learned as to what to do and what not to do in handling this soil. In its native condition this soil is almost entirely devoid of vegetation, that which does occur being limited to the small sand knolls which are found here and there.

Table IV gives the results of the mechanical analyses of a number of samples of soil taken from various parts of the hard land of the experiment farm. A number of these samples show a large percentage of fine gravel and coarse sand, and correspondingly small percentages of the finer materials. These samples represent the sand knolls, and though the figures show a marked difference in the physical structure of the soil this difference can hardly be detected in working the soil in the field, particularly so far as initial productivity is concerned. In fact, the lack of correlation between the results obtained from the mechanical analyses and the behavior of the soil in the field makes it evident that there is some cause other than mechanical texture which makes this soil so difficult to handle.

TABLE IV.—*Results of the mechanical analyses of samples of soil typical of the clay flats on the Truckee-Carson Experiment Farm.*[a]

Depth.	Hole.	Fine gravel (2–1 mm.).	Coarse sand (1 to 0.5 mm.).	Medium sand (0.5 to 0.25 mm.).	Fine sand (0.25 to 0.1 mm.).	Very fine sand (0.1 to 0.05 mm.).	Silt (0.05 to 0.005 mm.).	Clay (0.005 to 0 mm.).
Inches.	*No.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
0–12	1	5.3	24.4	23.7	32.4	3.9	3.2	6.4
0–12	2	1.2	9.5	7.3	30.9	16.0	18.4	16.3
0–18	7	.7	7.0	8.2	37.4	15.6	17.2	14.1
0–32	9	.9	5.5	5.3	21.1	6.8	27.9	32.2
0–20	19	2.0	10.2	9.4	41.5	9.4	7.9	19.4
0–12	22	3.1	16.4	12.9	34.7	10.3	8.2	14.3
0–12	23	.8	8.2	12.4	49.7	10.5	6.2	12.4
0–24	24	2.9	6.5	5.2	22.8	11.9	26.1	23.9
0–32	25	.4	2.4	2.9	30.4	22.4	22.6	19.2

[a] Analyses made by the Bureau of Soils, U. S. Department of Agriculture.

It has been noted that the desert soils, of which the experiment farm is typical, are generally deficient in organic matter. It is believed that much of the apparent infertility and other difficulties found on the hard lands are due to the lack of this constituent. Analyses made of four samples of soil from different parts of the hard land on the experiment farm showed the following percentages of organic matter:

TABLE V.—*Results of analyses, showing the percentages of organic matter in samples of soil from the clay flats of the Truckee-Carson Experiment Farm.*[a]

Depth of sample.	Hole.	Organic matter.
Inches.	*No.*	*Per cent.*
0–12	1	0.19
0–12	2	.31
0–32	9	.56
0–20	19	.17

[a] These determinations of organic matter were made by Miss J. R. Pearce. The soil samples were first digested with strong HCl to remove the carbonates, then heated to redness in the presence of oxygen, and the CO_2 formed was collected in caustic potash and weighed.

In order to make a comparison, it may be said that fertile soils rarely contain less than 1 per cent of organic matter, while rich prairie soils often contain much more. According to Hilgard,[b] the prairie soils of North Dakota contain in the first 6 inches from 15 to 26 per cent of organic matter, with a humus content ranging from 4 to 7.8 per cent. Soil samples from Dalhart, Tex., where the climate is semiarid and the soils are regarded as deficient in organic matter, show by the same method as that used in analyzing the Fallon soils slightly over 1 per cent of organic matter.

A chemical analysis, after acid digestion made upon seven samples of soil from a typical tract of hard land near the experiment farm, shows the following results, the figures being the average of those obtained from the seven analyses which were made by the Bureau of Soils: Phosphoric acid (P_2O_5), 0.17 per cent; lime (CaO), 1.71 per cent; magnesia (MgO), 1.40 per cent; potash (K_2O), 0.82 per cent.

The prompt subjugation of this hard land, where no troubles with alkali are involved, will require the use of some farm implements not usually found on western farms. The aim should be to get a good mellow seed bed established without turning up the raw subsoil, and particularly to keep the surface soil mellow and fine until the crops are high enough to shade the ground. This latter aim is very important. For preparing a fine, mellow seed bed, the disk, a turning and slicing harrow, and the ordinary spike-toothed harrow make a very satisfactory combination of implements. Sometimes the corrugated roller (see Pl. II, fig. 1) will do much better work after the turning and slicing harrow than the smoothing harrow. For keeping the soil surface mellow and warm after the crops are planted and until they are high enough to shade the ground the corrugated roller and the steel-toothed weeder do the work very well. The corrugated roller

[b] Soils, p. 133.

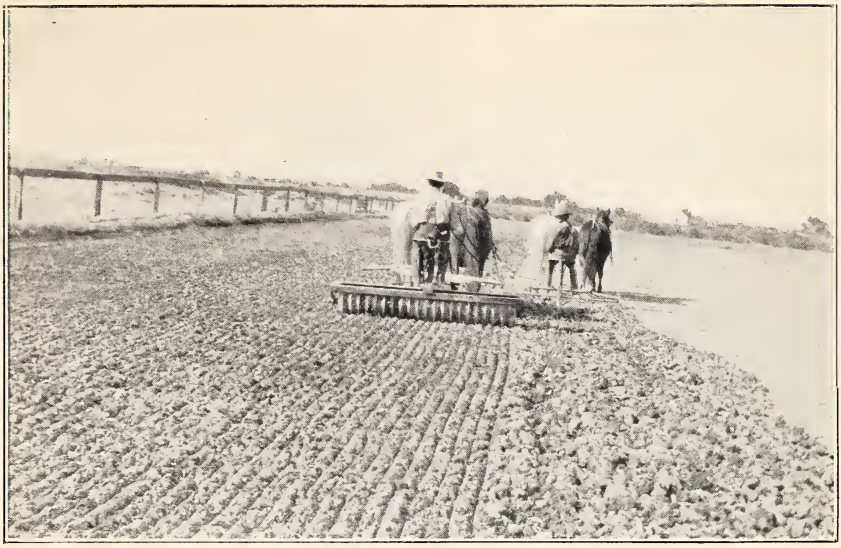

FIG. 1.—A TURNING AND SLICING HARROW, FOLLOWED BY A CORRUGATED ROLLER, IN USE IN PREPARING A SEED BED ON THE "HARD LAND" OF THE TRUCKEE-CARSON EXPERIMENT FARM. (PHOTOGRAPHED AUGUST 25, 1908.)

This land had been previously irrigated by flooding and a hard crust had formed, which these implements are effectually breaking up.

FIG. 2.—SURFACE OF THE "HARD LAND," SHOWING HOW THE SOIL BAKES AND CRACKS WHEN IT DRIES UNDISTURBED AFTER IRRIGATION.

Small plants are either killed or severely injured in this soil unless this baking and cracking can be prevented by cultivation.

seems to be absolutely essential for this work. The harrow or the weeder alone will not do. The roller can be used without injury to the small grains until the plants are 4 or 5 inches high. Following the roller the weeder does very excellent work, fully repaying its cost even on a small acreage.

It has been found that in order to get satisfactory results from this soil it should not be stirred deeper than is absolutely necessary to get a seed bed. Deep plowing or removing the surface soil for leveling purposes results in bringing to the surface soil which is very infertile and difficult to work. If the surface soil is not buried in the preparation of the seed bed, much better results are secured.

The hard land takes water very slowly, and during an ordinary flooding is not penetrated to a depth of more than 6 or 8 inches. It was found, in fact, that on some plats after an entire summer, during which the land was irrigated at intervals of two or three weeks, there were places where moisture had not penetrated beyond 18 inches and where the soil was so hard that holes could be dug only with the greatest difficulty.

In some cases the soil on these clay flats contains alkali, but this is by no means always the case; in fact, the larger part of the trouble with these soils seems to be due to their mechanical rather than to their chemical composition.

The relative impenetrability of soils of this hard land is well illustrated by an investigation made in an alfalfa field adjacent to the experiment farm. The field as a whole was fairly good, but it contained a number of spots irregular in size and shape, where the alfalfa plants were only from 3 to 6 inches high, while on the remainder of the field the plants grew to a height of 30 inches or more.

The boundaries of these areas of poor growth were found to be sharply defined. Thus, in a distance of 4 feet plants would increase in height from 3 to 30 inches. An examination of the poor spots, as compared with the areas where the growth was good, showed that in the poor spots the alfalfa roots did not penetrate beyond 10 inches, while on the land where the alfalfa was good the roots penetrated to a depth of 3 feet or more. The roots of the small plants were apparently unable to penetrate the hard soil beyond the depth of 10 inches. At this point many of the taproots branched and spread out irregularly, instead of pushing on into the subsoil as they usually do.

A careful comparison of the soils on the good and poor spots in this field showed that the soil of the poor spots was very slightly finer in texture, containing a larger proportion of clay. It was apparent, however, that the chief difficulty on these poor spots was that the irrigation water had not penetrated beyond the depth to

which the roots were found to have extended, and only the upper 8 inches was found to be wet. Below this depth a layer of soil about 1 foot thick was very hard, the particles being cemented together. Below this hard layer the soil was more open, and at a depth of about 4 feet the underground water was reached.

An examination of this soil to determine the salt content in the good and poor spots brought out the fact that in the good soil the percentage of soluble material was very much lower than in the poor soil, and particularly was this difference marked at the lower limit of water penetration. The indications were that in the poor spots the irrigation water had failed to penetrate the soil to join the water table, and thus carry down the excess salt.

The best results in handling these clay flats are likely to be secured where they are first heavily irrigated, to secure thorough penetration of water, and afterwards given a thorough cultivation. There is apparently nothing to be gained and much to be lost by deep plowing this land, at least until the soil is thoroughly subdued. After a thorough irrigation the soil may be worked into good tilth if the proper implements are used, and if care is taken in getting the crop started there should be little difficulty in securing a fairly good stand of grain or alfalfa on the land the first year.

The aim should be to get organic matter into these soils as rapidly as possible. Green-manure crops and coarse manure should be worked into the soil, and the surface tilth should be kept good to aid decomposition and humus formation. The greatest care should be used in the irrigation and tillage of the hard lands. If possible, the crop should be planted after an irrigation, and should be allowed to grow enough to shade the ground before the second irrigation is given.

Unless the ground is shaded, the crust formed after an irrigation, or even a light rain, is very hard and impervious, and seems to choke the young plants and almost completely check their growth. (See Pl. II, fig. 2.) In breaking this crust when the plants are young the corrugated roller, followed by the horse weeder, does very effective work. These instruments can be used to advantage even when the grain or alfalfa is several inches high.

In view of the obvious need of this hard land for aeration and organic matter it would seem the best practice to get alfalfa started on it as soon as possible. Once established, alfalfa does fairly well, and after this crop the land will certainly be much improved for other crops.

THE SANDY SOILS.

The sandy soils on the experiment farm, as elsewhere in the project, present a very different set of problems from the hard lands. They

respond to tillage and with a few exceptions appear to be immediately fertile. They are generally deficient in organic matter, and can be greatly improved by manure or a season or two in alfalfa. They are liable to wind injury and must be kept covered by crop or stubble after the native brush cover is removed. Their water-holding capacity is low and they require frequent irrigation. Water moves through them rapidly, and where the underground water is close to the surface there is danger of the surface accumulation of alkali.

Even the sandy soil forms a thin crust after irrigation unless cultivated, and the evaporation of water from the soil surface after irrigation is very rapid unless the ground is stirred and a surface mulch is made. This surface mulch is extremely important, not only in checking the rise of alkali, but in keeping up the temperature of the soil. A moist soil surface cools the soil just as a moist wrapping cools a water jar. Many crops are extremely sensitive to low temperatures in the spring, and make very slow growth while the soil remains cold. Thorough cultivation as soon as possible after irrigation practically stops evaporation from the soil surface and permits the soil to warm up.

Farmers are inclined to do no more cultivating than is required to keep down weeds. The necessity for weeding is slight on this new land, and it is a serious mistake to limit cultivation to that object alone. The land should be cultivated after each irrigation, whenever possible, whether there are weeds to kill or not.

COOPERATIVE EXPERIMENTS.

Much of the experimental work on the farm is conducted in cooperation with, and under the direction of, various experts and specialists in the Bureau of Plant Industry, in the Forest Service, and in the Nevada Agricultural Experiment Station.

The results of these experiments and investigations will in many cases be published by the men in charge of the work. It will suffice here to give a brief account of the lines of work thus far undertaken, with such of the results as are immediately and directly applicable to local conditions.

FORAGE AND GREEN-MANURE CROPS.

In view of the apparent need of putting organic matter into the soils of the experiment farm, almost the first efforts made in crop production were in the direction of producing forage and green-manure crops, including grasses. These experiments were made in cooperation with Mr. C. V. Piper, of the Bureau of Plant Industry.

A considerable number of these crops were planted in the spring of 1907 on the clay lands of series 1 and 2 (see fig. 2). Redtop, rape, and sweet clover were the most promising of the series. None of the crops tried was thoroughly satisfactory, and it was apparent that on the clay lands only the three mentioned can compete with alfalfa in vigor of growth. It now seems certain that in subduing the clay land the best results may be expected where spring grain and alfalfa are sown and the alfalfa is later plowed under after a good stand has been secured.

In view of the need of pasture lands for work stock and cattle a number of mixtures of grasses were tried in 1907, and again in 1908. The most promising single grass so far tried is redtop. This appears to do very well, not only on the clay lands, but it makes a vigorous growth along the ditch banks and almost anywhere where the moisture supply is adequate. Mixed with perennial rye, slender wheatgrass, and white clover or alsike clover a very good pasture may be established. There are indications, though no absolutely definite information, that artificial inoculation for clover and possibly also for alfalfa will give beneficial results.

SUGAR BEETS.[a]

In the spring of 1907 an acre of land was planted to nineteen varieties of sugar beets. This land was typical of the clay lands, although not of the heavier and most difficult type. In 1908 beets were planted both on the clay land and on the sandy soil. Those on the sandy soil were badly injured by sand storms early in the season and their later growth was seriously checked. On the clay land, however, the growth was good, although the stand was cut down by the ravages of rabbits. This made it impossible to obtain accurate information as to the comparative yields of the varieties, though estimates based on a plat of a quarter acre indicated a yield of about 12 tons per acre. Samples of each variety were analyzed and the results of these analyses are given in Tables VI and VII.

[a] The work with sugar beets was conducted in cooperation with Dr. C. O. Townsend, of the Bureau of Plant Industry.

TABLE VI.—*Results of analyses of sugar beets grown on the Truckee-Carson Experiment Farm, 1907.*[a]

Variety.	Source of seed.	Weight after topping.	Sugar in juice.	Purity.
		Ounces.	*Per cent.*	*Per cent.*
"Original" Kleinwanzleben		13	20.40	82.90
"Old Type" Kleinwanzleben		11	24.60	84.20
"Pioneer" Kleinwanzleben		15	23.40	87.00
Kleinwanzleben	Washington State	19	18.70	80.26
Kleinwanzleben, No. 17509		16	22.70	87.30
"Original" Kleinwanzleben, No. 17968		12	19.80	88.80
Schreiber's Speeial, No. 17969		10	20.80	90.85
No. 17979	Dippe Bros.	16	19.00	85.95
Kleinwanzleben, No. 17972		16	19.00	89.20
Kleinwanzleben, No. 17973	Lehi, Utah	18	22.10	87.70
Kleinwanzleben, No. 17974	Sugar City, Idaho	15	21.70	89.30
Kleinwanzleben, No. 17975	Herning & Co., Germany	14	22.00	88.00
Kleinwanzleben, No. 17976	Mette & Co., Germany	13	19.40	86.22
Kleinwanzleben, No. 17977	Germany	14	21.00	90.13
Kleinwanzleben, No. 17978	Bohemia	15	22.70	92.66
Kleinwanzleben, No. 17979	Holland	13	(b)	(b)
Kleinwanzleben, No. 17980	Briensted, Germany	12	23.30	88.87
Knaw's Mangold, No. 18235		12	22.60	86.69
Knaw's Mangold, No. 18835		13	23.70	86.68

[a] Analyses made by the Bureau of Chemistry, U. S. Department of Agriculture.
[b] Juice lost.

It will be noted that of the nineteen varieties tested thirteen have 20 per cent or more of sugar in the juice.

TABLE VII.—*Results of analyses of sugar beets grown on the Truckee-Carson Experiment Farm, 1908.*[a]

Variety.	Source of seed.	Soil type.	Weight after topping.	Sugar in juice.	Purity.
			Ounces.	*Per cent.*	*Per cent.*
Kleinwanzleben, No. 21839	Lehi, Utah	Clay	21	16.7	85.2
		Sandy	9	21.1	91.7
Kleinwanzleben Bremstedts, No. 21840.	Harz, Germany	Clay	21	18.7	90.3
		Sandy	5	19.2	89.8
Kleinwanzleben Mette, No. 21841.	Quedlingburg, Germany	Clay	19	17.2	86.8
		Sandy	11	20.3	88.3
Zuekerreiehet, No. 21842	Prague, Bohemia	Clay	16	18.3	87.8
		Sandy	11	20.7	91.6
Aderstedts, No. 21843	Magdeburg, Germany	Clay	19	20.8	86.6
		Sandy	16	18.9	89.9
Kleinwanzleben Braune, No. 21844.	Brendorf, Germany	Clay	18	18.1	86.2
		Sandy	16	17.0	82.5
Kleinwanzleben Heine, No. 21845.	Hadmersleben, Germany	Clay	24	17.6	85.4
		Sandy	16	20.2	89.0
Kleinwanzleben, No. 21846	Fairfield, Wash	Clay	24	16.6	84.6
		Sandy	24	19.5	89.2
Kleinwanzleben, No. 21847	do	Clay	24	19.4	92.4
		Sandy	6	20.6	93.2
"Old Type," No. 21848	Klein Wanzleben, Germany.	Clay	28	18.8	87.0
		Sandy	11	20.2	89.8
Kleinwanzleben Strandes, No. 21849.	Anhalt, Germany	Clay	24	16.9	86.6
		Sandy	11	19.3	88.9
Kuhn Kleinwanzleben, No. 21850.	Naarden, Holland	Clay	28	18.6	86.9
		Sandy	19	19.0	85.2
Behren Kleinwanzleben, No. 21851.	Magdeburg, Germany	Clay	28	17.6	88.0
		Sandy	5	21.0	90.9
Horning Kleinwanzleben, No. 21852.	Eisenleben, Germany	Clay	24	17.8	85.5
		Sandy	5	20.1	90.5
Jaenseh, No. 21853	Aseherleben, Germany	Clay	28	17.5	88.8
		Sandy	11	20.7	90.3
"Original" Kleinwanzleben, No. 21854.	Klein Wanzleben, Germany.	Clay	24	20.0	89.5
		Sandy	11	20.1	91.3
Schreiber's Specialitate, No. 21855.	Nordhausen, Germany	Clay	28	18.6	92.5
		Sandy	11	20.7	95.8
"Pioneer" Kleinwanzleben, No. 21856.	Klein Wanzleben, Germany.	Clay	24	18.2	89.2
		Sandy	5	20.5	87.5
Wohanka Kleinwanzleben, No. 21857.	Prague, Bohemia	Clay	24	16.8	83.7
		Sandy	4	20.3	91.8
Dippe's Elite Kleinwanzleben, No. 21858.	C. O. Townsend	Clay	20	18.4	92.0
		Sandy	5	19.9	.....
Kleinwanzleben, Idaho, No. 21859.	Sugar City, Idado	Clay	24	19.2	87.6
		Sandy	6	19.5	91.8

[a] Analyses made by the Bureau of Chemistry, U. S. Department of Agriculture.

HORTICULTURAL EXPERIMENTS.

No experiments with horticultural or fruit crops were undertaken in 1907. In the spring of 1908 a number of varieties of orchard fruits and small fruits were sent to the farm by Prof. P. Beveridge Kennedy, of the Nevada Agricultural Experiment Station.

POTATOES.

The work with truck crops was begun in the spring of 1908, and in addition to the fruits just mentioned five varieties of potatoes were planted, the seed being furnished by Prof. L. C. Corbett, of the Bureau of Plant Industry.

The varieties under trial were Rural New Yorker, Delmany Challenge, Peachblow, and two unnamed varieties, Nos. 475 and 476. The potatoes were irrigated every ten days. Of the varieties mentioned Delmany Challenge and Rural New Yorker yielded larger crops of marketable potatoes than did the other varieties. Owing to the lack of uniformity in stand and to the fact that these potatoes were not grown under comparable conditions, no estimate can be given of the yields per acre.

Seeds of a number of varieties of vegetables, also furnished by Professor Kennedy, were planted, but the land used was but newly leveled, and the many irregularities in the plats made it impossible to judge of the relative merits of the varieties.

Wherever possible, potatoes should be planted following alfalfa, This practice is followed in the vicinity of Greeley, Colo., where excellent results are secured. The present indications are that potatoes planted on new land will not yield so well nor will the appearance and quality be so good as where they are planted after alfalfa, or even on old land after grain. In the Greeley region a five-year rotation is used with conspicuous success, consisting of three years of alfalfa, followed by potatoes, followed by grain with which alfalfa is seeded.

Potatoes will probably be a most important truck crop for new settlers. The quality of potatoes produced on the project is usually very good, but much influenced by the treatment given. This makes it important that each farmer give the matter of irrigation and cultivation careful study, since not only the yields but the quality of the crops are very markedly influenced by this treatment.

CORN.

In 1907 a number of varieties of corn were planted on the clay lands of series 1 and 2. A few of these varieties matured, but none made good growth or yielded well. It is apparent that corn can not

be profitably grown on this heavy soil while it is new and before a considerable amount of organic matter has been put into it.

In 1907 seventeen varieties of corn were planted on the sandy land of the farm, the seed being furnished by Mr. C. P. Hartley,[a] of the Bureau of Plant Industry. These varieties were planted May 11. Several severe frosts occurred after this date, and the growth was very slow during May and early June. The stand, however, was fairly good, and after June 15 the growth was rapid. The plants appeared healthy and vigorous. All of the varieties eared well, and at the time of the first killing frost (September 26) all but three or four of the latest ones had matured.

Considerable injury was inflicted on these corn varieties by blackbirds, so that comparative yields could not be secured. Had the experimental field been larger, or had there been a considerable quantity of corn in the neighborhood, this injury would have been, of course, materially reduced. The indications are that a considerable number of rather early maturing varieties, such as Leaming, Iowa Silver Mine, and the earlier strains of Reid's Yellow Dent, will give good results. While larger yields may be obtained in some years from the heavy-yielding, late-maturing varieties the danger of early frosts is sufficiently great to make it desirable to use only the early-maturing varieties at present. There is apparently nothing to be gained by planting corn before May 15 or 20, as the early corn is often severely checked by the cold weather in late May and early June.

As has been suggested for potatoes, the best results with corn may be expected where the crop follows alfalfa. In fact, such crops as sugar beets, potatoes, and corn should invariably be planted on old alfalfa land, and wherever possible this alfalfa land should be given a top-dressing of manure in the winter or early spring, plowed in April, and put into the best possible tilth before the crops are planted.

ALFALFA EXPERIMENTS.

In addition to field experiments where alfalfa is used both as a forage crop and to improve the soil, experiments with this crop plant are being carried on under the direction of Mr. C. J. Brand, of the Bureau of Plant Industry, in which thirty-two strains and varieties of alfalfa gathered from as many different sources, both in this country and abroad, are being studied.

Three different methods of planting were used with each variety. Plats 1 rod by 2 rods were planted in drill rows 6 to 8 inches apart. Single rows of each variety were planted, the rows being 36 inches

[a] The field work was done under the direction of Mr. L. L. Zook, who has contributed the report which follows.

apart to permit intertillage. Also seed of each was planted in hills 36 inches apart each way, and later thinned to one plant in each hill.

It is the aim to observe the relative behavior of these strains planted in these different ways in order to note the reactions of each to the different conditions presented, and from these studies to learn the causes of the success or failure of each.

TREE PLANTINGS.

In the spring of 1908 about 5 acres of the sandy land of the experiment farm was planted to trees in cooperation with the Forest Service. These trees were one and two year old seedlings from a nursery in Nebraska and included cottonwood, honey locust, black locust, willow, and Russian olive. The trees were set 6 feet apart each way, irrigated by flooding, and cultivated from time to time. Late in the season the rabbits caused considerable damage by girdling some of the trees. This was effectually checked by painting the trees with white lead. The cottonwoods and honey locusts did the best in the field planting, while the Russian olive, which was set along the ditch banks, made very rapid growth. Tamarisk cuttings, obtained locally, were set along some plat borders and made a growth of 6 to 8 feet the first season.

EXPERIMENTS ON ALKALI LAND.[a]

Alkali occurs in various parts of the Truckee-Carson Project, especially in low places where the ground water is near the surface of the soil and where the drainage from surrounding higher ground has accumulated by seepage. The greater part of the alkali is found in the heavier soils, but some of the light sandy soil is also more or less salty.

As a rule it will be possible to get rid of the alkali by drainage and heavy flooding. This will be comparatively easy to accomplish in the lighter soils, provided the ground water table can be kept down. In the heavier soils, however, the physical condition of the soil is a serious obstacle to its reclamation on account of the puddling effect of the alkali salts, making the penetration of water difficult.[b]

The addition of organic matter is one of the most effective means of improving the physical condition of heavy alkali soils. This can be

[a] The chapter describing the alkali conditions and the experiments with crops for alkali land has been prepared by Mr. T. H. Kearney.

[b] Certain types of alkali, unless present in excessive amounts, probably cause as much damage indirectly by their effect upon the physical condition of the soil as by their direct physiological action upon the plants. Not only do the alkali salts, when present in heavy soils, hinder the penetration of water, but they help to form a hard crust on the surface, which seedling plants find difficulty in breaking through.

done by disking in coarse farm manure or by growing and plowing under a green crop, using some specially alkali-resistant species.

Under ordinary conditions the growing of resistant crop plants is not to be recommended as a final solution of the alkali problem, but they will often aid in preparing the way for more valuable crops. In places where the local conditions will not permit reclamation by drainage, or where the cost of drains is for any reason prohibitive, it may be necessary to continue growing resistant crops. Seeding such land, especially if the water table is near the surface, to some of the perennial meadow and pasture grasses which will stand considerable alkali, is probably the best solution of the problem which can be offered at present.

CHEMICAL COMPOSITION OF THE ALKALI.

The alkali found on the project is a less harmful type than that which occurs in many localities,[a] the predominating salt being sodium sulphate with sodium chlorid and sodium bicarbonate occurring as secondary components. Alkali of this type is generally less harmful to plant growth than that in which sodium chlorid is the principal salt. Black alkali (sodium carbonate) occurs in places on the project, although usually forming only a very small percentage of the total salts. Where this salt is present in such quantity as to amount to one-twentieth of 1 per cent of the dry weight of the soil, it becomes a serious menace to plant growth, through its corrosive action on the plant tissues. Sodium carbonate, more than any other salt, tends to puddle the surface of the soil and prevent leaching under irrigation. In places where an excess of this salt occurs, treatment with land plaster (calcium sulphate) may be necessary in order to neutralize the free alkali.

Where sodium carbonate is absent, or present only in small quantities, a considerable variety of crop plants can be grown with proper management in the presence of an average of one-half of 1 per cent of alkali in the first 3 feet of soil. The chief precautions necessary are to wash the alkali down out of the upper few inches of the soil

[a] Experiments in the greenhouse with a considerable number of different grasses and leguminous forage plants grown in alkali soil from Fallon and from other localities in the West, showed the Fallon alkali to be less harmful with the same percentage of salts to dry weight of soil and the same concentration of soil solution than the one in which the bulk of the alkali was sodium chlorid. Where only 0.2 per cent total salts to dry weight of soil was present, and the percentage of soil moisture was about the optimum for plant growth in the type of soil used, the Fallon alkali had an actually stimulating effect on the germination of grasses.

at the time of seeding and to prevent the soil becoming very dry at any time during the growing season.[a]

RESISTANT CROP PLANTS.

As a result of the experiments in 1907 and 1908, it was found that a number of species are decidedly more resistant to alkali than others. One of the most resistant crop plants is the sugar beet, and some of the cereals are also able to make a limited growth and even ripen a small amount of seed in the presence of as much as 1 per cent of alkali. But in both of these classes of crops the value of the product is injured by an excessive amount of alkali. In the case of the sugar beet, the purity coefficient is seriously impaired, even though roots of good size are formed. The seed ripened by the cereals in strong alkali soils is generally small and shrunken, and hence of little value.

On the other hand, with forage plants it is only necessary to get a good development of leaf and stem to make them valuable. If this is accomplished they may serve for pasturage and hay, and also as green-manure crops, which can be plowed under and thus greatly improve the physical texture of alkali soils. Often the improvement of texture thus brought about by making the soil more permeable to water insures its being easily reclaimed by washing out the excess of salts.

Among the forage plants found to make a good growth in the presence of large amounts of alkali, some of the grasses take the first rank. Western wheat-grass (*Agropyron occidentale*), tall meadow oat-grass (*Arrhenatherum elatius*), smooth brome-grass (*Bromus inermis*), tall meadow fescue (*Festuca elatior*), and Italian rye-grass (*Lolium italicum*) were found to be especially tolerant of alkali. With proper management a good stand of any of these grasses can probably be secured in the presence of from one-half of 1 per cent to 1 per cent of total salts in the first 3 feet of the soil, in case there is no considerable amount of black alkali present. Italian rye-grass seems to be especially promising as a rapid-growing lawn and pasture grass for alkali soil. Unfortunately, it is a short-lived grass and will have to be reseeded every year or two.

Other grasses that are probably less resistant than the preceding, yet should do well in the presence of nearly or quite one-half of 1 per cent of total salts, are slender wheat-grass (*Agropyron tenerum*), redtop (*Agrostis alba*), orchard grass (*Dactylis glomerata*), and

[a] The harmfulness of a given percentage of salts to dry weight of soil of course depends largely on the amount of moisture present, which determines the concentration of the soil solution. One-half of 1 per cent of salts may be practically harmless to a given species in a moist, but fatal in a dry, soil.

perennial rye-grass (*Lolium perenne*). In fact, it would appear that most of the standard meadow and pasture grasses are more or less alkali resistant.

The German or Hungarian millet proved to be decidedly alkali resistant, and was found to make a practically normal growth and to head out where there was one-half of 1 per cent of alkali in the first foot of the soil, and 1 per cent in the second.

Considerable tolerance for alkali was shown by some of the sorgos and milos. Dwarf milo was able to make about one-half of its normal growth and to mature small heads in the presence of very nearly 1 per cent of total salts in the first 3 feet of the soil. Amber sorgo made a corresponding growth and headed out in places where the alkali content of the first 3 feet of the soil amounted to one-half of 1 per cent.

The leguminous forage plants are much less resistant than the grasses. The best results were obtained with sweet clover (*Melilotus alba*). This plant made a good growth where there was three-tenths of 1 per cent of alkali in the first foot of soil, and 1 per cent in the second foot, about three months after seeding. A smaller but still healthy growth was made in the presence of seven-tenths of 1 per cent in the first foot, 2½ per cent in the second, and more than 3 per cent in the third foot. Two-year-old plants, 4 feet high, were found to be ripening seed where there was nearly three-tenths of 1 per cent of alkali in the first 3 feet of the soil, with considerable black alkali present.

Canada field peas and horse beans (*Vicia faba*) were found to be fairly resistant to alkali in the young stage of growth, but neither of these species seems to be able to stand the hot summers at Fallon. The plants rapidly dried up after the first of July. The hairy vetch (*Vicia villosa*) can endure the presence of one-half of 1 per cent of salts in the first 3 feet of soil, but remains in a dwarfed state under these conditions. Where the alkali does not exceed 0.2 or 0.3 per cent this vetch will probably be found to be one of the most successful leguminous forage plants.

Among the most alkali-resistant plants tested were Essex rape and thousand-headed kale. A good stand and fair growth of both these species can be secured in the presence of nearly or quite 1 per cent of total salts in the first 2 or 3 feet of the soil.

Certain native grasses of the project, notably slender water grass (*Leptochloa fascicularis*) and barnyard grass, the seeds of which are widely distributed with the irrigation water, are able to stand a considerable amount of alkali, and are of some value for wild-grass hay and pasturage.

CROP PLANTS RECOMMENDED.

Wherever conditions make it feasible, it is desirable to reclaim alkali land by washing out the salts rather than to rely upon resistant crop plants for its utilization. During the process of reclamation, however, it is preferable to grow something on the land rather than to leave it fallow, especially as the addition of organic matter to such land improves its texture, and thus not only facilitates washing out the salts, but makes the conditions more favorable for seeding to less resistant crops after reclamation is completed. German millet, rape, kale, and sweet clover are the most promising green-manure crops for alkali soils. Resistant crops that can be intertilled, and thus also aid in reclamation, are sugar beets, kafir, milo, and the cane sorghums. If for any reason reclamation by flooding and drainage is impracticable, it will probably be most advantageous to seed the land to some of the perennial grasses mentioned, either singly or in mixture.

INDICATOR PLANTS.

In selecting land for farming in irrigated districts it is very important to ascertain whether there is any considerable amount of alkali present, either near the surface or at lower depths in the soil. In the latter case there is always danger that the application of irrigating water for a number of years and the consequent raising of the water table will bring the salts to the surface.

The best indicator of the presence of alkali in the virgin land is the character of the native growth upon it. Where such comparatively short-rooted species as salt-grass (*Distichlis spicata*), blueweed (*Heliotropium curassavicum*), mintweed (*Iva axillaris*), and saltwort (species of Suæda) occur, the surface soil is usually moist and the alkali salts are already accumulated there. It then becomes a question of determining the amount of salts present and the possibility of getting rid of them by drainage. The presence of certain larger, deeper rooted species, even though associated with small, shallow-rooted plants that do not indicate the presence of alkali, is a warning that considerable amounts of soluble salts occur at greater depths in the soil, and the possibility must always be borne in mind that this alkali is likely subsequently to come to the surface, preventing the growth of crops. Native plants in the latter category are the larger saltbushes (species of Atriplex), rabbit brush (species of Chrysothamnus), and greasewood (*Sarcobatus vermicularis* and *S. baileyi*). The presence of greasewood is an almost certain indication that alkali occurs somewhere within reach of its roots.

SUMMARY.

The Truckee-Carson Irrigation Project lies near the western edge of the Lahontan basin, in western Nevada. The water supply is drawn from the combined flow of the Truckee and Carson rivers.

The climate is one of moderate temperatures, low rainfall with low atmospheric humidity, and few cloudy days.

The good railroad facilities and the mining camps in adjacent hills provide an outlet to good markets for the agricultural products.

There are three important classes of soils on the project, the river and lake bottom lands, which contain an abundance of organic matter and are immediately fertile where the alkali is not injurious, the sandy desert soil, and the clay desert soil. The desert soils are deficient in organic matter. The sandy soils are easy to work, but are likely to be blown about by the occasional windstorms. The clay soils are at first difficult to work, but once put in good condition by the addition of organic matter they bid fair to be very valuable.

There has been some agriculture on the project along the Carson River for half a century. The present agricultural development, however, dates from 1905, when the present irrigation works were completed.

The earlier agriculture of the project was centered around livestock production, and present indications are that some form of stock farming must have a large place in the future agricultural development. Heavy truck crops, fruits enough for local needs, and sugar beets are promising as subsidiary lines.

The Truckee-Carson Experiment Farm, located 1 mile south of Fallon, Nev., is operated by the United States Department of Agriculture in cooperation with the Nevada Agricultural Experiment Station and the United States Reclamation Service. The farm includes 160 acres, of which about 40 acres are now under crop.

The experimental work is for the most part conducted under the direction of experts and specialists in the Department of Agriculture and the Nevada State station.

Experiments in subduing the clay land show that it should not be plowed deep at first, and that special farm implements and careful irrigation are necessary to get crops started.

The sandy soils show the need of great care in preventing the exposure of new land to the action of wind during the spring.

Experiments with forage and green-manure crops show that redtop, rape, and sweet clover are best adapted to the heavy soils, when first broken.

Two years' experiments with sugar beets show that good crops of beets of a high sugar content may be expected.

Potatoes of excellent quality can be produced, and good crops of corn are possible. Either winter or spring wheat may be grown, and oats and barley yield well.

Alfalfa, the most important crop of the region, yields two or three cuttings each year, besides improving the land for other crops.

The region is nearly timberless, and extensive tree plantings should be undertaken, not only to provide wind-breaks, but also for fuel. The cottonwood and the honey locust do well, while the tamarisk makes quick growth along ditch banks and field borders.

Experiments with alkali land to find the plants most resistant to alkali show that such crops as sugar beets, sorghum, and some grasses may be grown on such land with proper care in tillage and irrigation.

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